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SUBJECT: Final Report of Carbaryl EEC's for Drinking Water, additional simulations
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This is an addendum to the final report for revised estimated environmental concentrations (EEC's) in surface water for the use of carbaryl on selected crops. This addendum provides additional EEC's that more fully describe the variation in exposure across the landscape. This has been done by adding additional two addition crops, peaches and pecans, and adding estimates for citrus in California to the estimates for citrus in Florida. These additional simulations are provided to more fully characterize exposure to carbaryl residues in drinking water from a variety of uses and (for the citrus use) to provide exposure estimates representing a variety of alternative scenarios (maximum application rates, application methods, application intervals)which could mitigate the predicted dietary risks from food plus water from the Florida citrus use. The additional exposure estimates further refine the risk and help localize the risk by identifying other crops that have high exposure, but do not fill the risk cup, (pecan, peaches, and apples) and by identifying locations where citrus is grown where the exposure is lower than Florida. These refinements will help segregate where risk mitigation practices may be necessary from those locations and crops where the risk is not expected to be exceeded. In addition to the EEC's, additional characterization of the exposure due to urban use has been included.

The EEC's in Table 1 represent the 90 percentile exposure value for carbaryl use on representative crops. These EEC's are based on the maximum use patterns allowed on each label as described below.

Table 1. EEC's for the 'maximum' use patterns for carbaryl on selected agricultural crops. Scenario with the highest EEC's (Florida citrus) are shaded.

Crop	Acute EEC	Chronic EEC
	--------------------- $\mu g\ L^{-1}$ carbaryl --------------------	
Apples (PA)	94.7	3.3
Citrus 1 (CA)	100.0	4.71
Citrus 2 (CA)	87.9	3.37
Citrus (FL)	410.4	18.6
Peaches (GA)	44.9	2.05
Pecans (GA)	48.2	2.16

A more complete description of rationale and effects of these changes is provided below. The revised EEC's for the maximum use pattern are in Table 1. A complete list of EEC's for all use patterns is in Table 6. The estimate for apples revises the maximum use pattern from 2 lb acre^{-1} to 3 lb acre^{-1} in accordance with the actual maximum label practice. The maximum use pattern for citrus is 7.5 lb acre^{-1} with a 20 lb acre^{-1} seasonal total, which was previously modeled with 4 applications of 5 lb acre^{-1}. To better reflect the exposure which may result from this use pattern, this pattern was simulated with 4 applications of 7.5 lb acre^{-1} in California, a total of 22.5 lb acre^{-1} per year, and with two application of 7.5 lb acre^{-1} and one application of 5 lb acre^{-1} in Florida. A use pattern with a single high application (16 lb acre^{-1}) to citrus was not modeled previously and has been added here as "Citrus 2 (CA)" in table 1.

Models

These estimates were calculated using PRZM version 3.12 dated May 24, 2001 and EXAMS version 2.98.04 dated July 18, 2002. These models were run in the EFED PRZM EXAMS shell, PE3 version 1.2, dated October 15, 2002. The shell also processed the output from EXAMS to estimate the 1 in 10 year return values reported here. In addition, time series of daily values for thirty years were output and have been provided for use in more refined dietary exposure assessment. A list of the input files used to generate these EEC's is in the Appendix. In some cases, runs with two different application rates were run and then recombined using Excel spreadsheets. The summary statistics for these runs were estimated manually. Florida citrus simulation 13 (2 applications of 7.5 lb $acre^{-1}$ and one application of 4 lb $acre^{-1}$ with 14 day interval applied by spray blast) was modeled by Dirk Young rather than R. David Jones. The PE4 shell (see below) was used for this simulation rather than PE3.

It is worth noting that the Office of Pesticide Programs is aware of an error in the current modeling system that results in the "peak" EEC's reported actually representing not instantaneous peak concentrations, but 24-hour mean concentrations on the day the peak occurs. The OPP is currently taking corrective action, but revisions had not completed QA review prior to initiation of this analysis. For the case of carbaryl, this likely results in an approximately five percent underestimation of the peak. However, this error is certainly covered by other substantial conservatisms which are inherent in these estimates. A new version of the post-processing and shell software "PE4" has now been approved by OPP for use and fixes these errors. It was not used here in order to maintain consistency with the previous carbaryl simulations but will be used for any future efforts.

Scenarios

EEC's were calculated for 5 crops which include those which are the major use sites for carbaryl. These sites are: apples, citrus, field corn, sweet corn, and sugar beets. The scenario for apples is in Lancaster County, Pennsylvania and represents a Elioak silt loam soil, Hydrologic Group C soil. The Florida scenario for citrus is in Collier and Hendry Counties Florida and represents a Wabasso sand soil. The California citrus scenario is in Fresno County and uses a Exeter loam soil in Hydrologic Group C. The peach scenario is in Peach County and has a Greenfield fine sandy loam soil in Hydrologic Group B. The pecan scenario is in Mitchell and Dougherty Counties and uses a Greenville fine sandy loam in Hydrologic Group C.

Use Patterns

The use patterns for each crop were adapted from the carbaryl labels to represent the maximum use patterns. The input parameters used to represent these use patterns are in Table 2. In cases where a minimum re-application interval was specified on the label this value was used in the maximum application pattern. In cases when no minimum interval is specified, a interval of 3 days was used. The OPP currently has no written guidance for this assumption However, three days is a reasonable minimum retreatment interval, given that scouting and evaluation of efficacy would have to occur before another treatment is undertaken. This minimum value has been used by OPP for Tier 2 modeling in the absence of guidance for 10 years. Metadata for each scenario is described in EFED, 2002b. As noted above, the apples and Florida citrus practices replace those for simulations in the document which this is an addendum

Table 2. Maximum use patterns for carbaryl application on selected crops based on the EPA label.

Crop	Single App. Rate (lb acre^{-1})	Number of Applications	Application Interval	Application Method	Date of First Application
Apples 1	3	5	3 days	aerial	June 1
Citrus: CA - 1	7.5, 5[1]	3	3 days	aerial	April 30
Citrus: CA - 2	16	1	NS	aerial	April 30
Citrus: FL - 3	7.5, 5[1]	3	3 days	aerial	April 30
Citrus: FL - 4, 5[3]	10	2	14	aerial	April 30
GA peaches	4.945	3	7 days	aerial	June 1
GA pecans[2]	5	3	7 days	aerial	April 15

1) Maximum single application of 7.5 lb acre^{-1}, 20 lb acre^{-1} per season, modeled as 3 applications of 7.5 lb acre^{-1}.
2) Four application per season are allowed for pecans, but only 15 lb acre^{-1} each year, or three applications at the maximum rate.
3) This use pattern was used to estimate EEC's for with both the default PCA of 0.87 and the provisional regional PCA for Florida of 0.38.

Several addition use patterns have been simulated in order to support risk management decisions and identify appropriate and sufficient mitigation practices. These are listed in Table 3. In all these additional simulations, aerial application, which is allowed on the label, has been replaced with spray blast, which is the most commonly used application method for orchard crops. Spray blast tends to result in much less drift than aerial application. Several of these simulations, namely Apples 2, Citrus 4, Citrus 9, Pecans 2 and 3 are the maximum application practice with the change to spray blast only. Apples 3 includes a reduction in the number of applications to three and an increase in the application interval to 14 days. According to analysis of usage data by BEAD (personal communication), this would represent a practice which is greater than 90% of the actual carbaryl use on apples. Citrus 7 and Pecans 4 are also use patterns that would represent approximately a ninetieth percentile according to BEAD. Citrus 11 and Pecans 3 do not represent different use patterns but reflect the use of a provisional regional PCA. This PCA is further described in the results section. Aerial application is represented by using a spray drift efficiency of 0.16 and an application efficiency of 0.95 while air blast is represented by values of 0.064 and 0.99 for these parameters respectively

Table 3. Selected use patterns for carbaryl application for evaluating mitigation practice effects on carbaryl in drinking water.					
Crop	Single app. Rate (lb acre^{-1})	Number of Applications	Application Interval	Application Method	Date of First Application
Apples - 2	3	5	14 days	spray blast	June 1
Apples - 3	3	3	14 days	spray blast	June 1
Citrus (CA) 6	16	1	--	spray blast	April 1
Citrus (CA) 7	12	1	--	spray blast	April 1
Citrus (CA) 8	8	1	---	spray blast	April 1
Citrus (CA) 9	7.5, 5[1]	3	14 days	spray blast	April 30
Citrus (FL) 10,11[2]	7.5, 5[1]	3	14 days	spray blast	April 30
Citrus (FL) 12	4	2	14 days	spray blast	April 30
Citrus (FL) 13[2]	7.5, 4[1]	3	14 days	spray blast	April 30
Pecans 2, 3[2]	5	3	7 days	spray blast	April 15
Pecans 4	2.5	2	10 days	spray blast	April 15

1) Two applications at 7.5 and 1 application a 5 lb acre^{-1}. For Citrus 13, the third application was 4 lb acre^{-1}.
2) This use pattern was used to estimate EEC's for with both the default PCA of 0.87 and the provisional regional PCA for Florida of 0.38.

Table 3.EEC's for carbaryl application to selected crops for evaluating mitigation practice effects on carbaryl in drinking water. The default PCA of 0.87 was used unless otherwise noted.					
Use Site/ application method	1 in 10 year Peak ($\mu g\ L^{-1}$)	1 in 10 Year Annual Mean	Maximum	percent over 100 $\mu g\ L^{-1}$	percent over 6 $\mu g\ L^{-1}$
	----------------------------- $\mu g\ L^{-1}$ ---------------------------				
Apples maximum	94.7	3.3	158	0.08	8.6
Apples - 2	86.6	3.2	153	0.08	8.3
Apples - 3	67.0	2.1	141	0.03	4.2
Citrus (CA) max 1	100	4.7	118	0.29	12.1
Citrus (CA) max 2	87.9	3.4	91.3	0.00	10.1
Citrus (CA) 6	34.6	1.3	35.8	0.00	6.6
Citrus (CA) 7	26.0	1.0	26.9	0.00	5.8
Citrus (CA) 8	17.3	0.66	17.9	0.00	4.1
Citrus (CA) 9	22.7	1.6	23.9	0.00	12.0
Citrus (FL) max 3	410.4	18.6	2085	13.4	16.2
Citrus (FL) max 4[1]	646.8	23.3	854	1.65	18.0
Citrus (FL) max 5[2]	237.9	8.6	373	0.68	14.3
Citrus (FL) 10[1]	395.0	19.1	602	13.4	18.9
Citrus (FL) 11[2]	172.8	7.0	322	0.52	9.6
Citrus (FL) 12[2]	108.7	3.8	141	0.10	3.6
Citrus (FL) 13[2]	204	6.7	263	0.38	9.7
Peaches - max	44.9	2.0	249	0.07	8.4
Pecans - max 1[1]	182.4	8.5	201.8	0.64	14.0
Pecans 2[1]	159.9	7.0	194.0	0.39	12.4
Pecans 3[2]	69.8	3.1	84.7	0.00	6.6
Pecans 4	21.0	0.94	109	0.03	5.6
1 Calculated with default PCA of 0.87 2 Calculated with provisional default regional PCA for Florida watersheds of 0.38					

Chemical Parameters

The chemistry input parameters were identical to those used in the simulations in the original memorandum document to which this is an addendum.

Results and Characterization

EEC's were calculated as described above and then adjusted for percent cropped area (PCA), based on OPP guidance (OPP, 2000). EEC's are in Table 3. In most cases, the default PCA of 0.87 was used, but for Florida citrus and Georgia pecan simulations, an additional set of EEC's was generated using a provisional default regional PCA of 0.38, ~~was used~~ see Table 3. The PCA represents the maximum amount of agricultural land in any watershed at the 8 digit hydrologic unit code (HUC) scale in the HUC 2 watershed area containing Florida. This regional PCA was calculated in a similar manner to that for the national default PCA, and these regional default PCA's were used in the OP cumulative assessment. The OPP is currently considering a policy for using regional default PCA's as a regular part of drinking water exposure assessment. For all the crops simulated in this assessment, the default PCA for all agricultural land of 0.87 was used. As before, the citrus scenario with the maximum use pattern is recommended in estimating EEC's for Tier II drinking water assessment.

A Tier II EEC uses a single site which represents a high exposure scenario for the use of the pesticide on a particular crop or non-crop use site. The weather and agricultural practice are simulated at the site over multiple (in this case, 30) years so that the probability of an EEC occurring at that site can be estimated. Sites are selected to represent a site which is more vulnerable than 90% of the sites which are used for growing the crop on a nationwide basis. Sites are currently selected to meet this standard by best professional judgement. For each simulation, the exposure of interest, either the annual peak or mean, is identified for each year. These 30 values are sorted and the single point estimate is selected by identifying the value that would be expected to recur once every 10 years. For these simulations, this specific value is linearly interpolated from between the third and fourth highest annual values.

These values are greater than those that would be expected to be found in the environment primarily for three reasons. First, we have used the default PCA of 0.87, as the PCA for citrus in Florida. The default PCA is the maximum proportion of agricultural land found in any basin in the country, In fact, the actual PCA in Florida is probably closer to one-third this value, although a precise estimate is not available at this time. Secondly, the percent crop treated has been assumed to be 100%. In fact, according to BEAD (Hernandez, 2002), the percent crop treated for different citrus crops ranges for 1.5 to 6%, depending on the crop. Thirdly, since the labels have not specified maximum number of applications, the maximum practice modeled is substantially greater than that which is usually used in practice. In particular, the rate per acre and the number of treatments per season is often less than that allowed on the label. In addition, the interval between applications (when there is more than one) is usually longer than has been simulated for the maximum use pattern. This third factor has been addressed in this assessment, and is reflected in the EEC's from the 'average' and maximum reported use patterns from Table 3 and 4.

In addition to the point estimate EEC's for drinking water exposure described above. We have provided the time series of concentrations for the entire duration of the simulation for the different citrus scenarios. These series of estimates are intended for use in a more full of the whole range dietary exposure for carbaryl and are being combined with pesticide residues in food using the DEEM model. While making fuller use of the whole time series for drinking water exposure is expected to improve the description of the dietary risk, using the time series for water in combination with the distribution of food residues and consumption patterns normally used in DEEM substantially alters the interpretation of the risk represented by the output of the model because the drinking water component introduces a time component which is not present in the food and consumption data - any time component in the data is ignored by DEEM. Technically, the food and consumption distributions are assumed to be 'stationary' with respect to time and location, that is the distributions are always the same at any point in time and any location in the United States. This is a reasonable assumption for food residues and consumption, but not a reasonable one for pesticide residues in drinking water which are expected to vary by orders of magnitude with both time and location. The difference in interpretation can be best illustrated by describing how the interpretation differs when the different exposure components dominate the exposure profile. When food (other than water dominates the exposure and the drinking water contribution is negligible, an exceedance of the 99.9% threshold implies that one person in 1000 across the whole U. S. population is above the threshold each day. If drinking water dominates and food contributions are negligible, an exceedance of the 99.9% means that the entire population provided drinking water from a facility represented by scenario, are expected to exceed the risk once every 1000 days, a little less that once every three years. When both water and food sources make significant contributions to exposure, a more detailed analysis of the structure of the data is necessary to determine the nature of the risk. Depending on the structure of the risk, regulating on the 99.9 percentile in a manner similar to that used previously may not provide a intended level of safety similar to that which is provided by using DEEM with food only and the DWLOC approach with water.

Beyond the three major factors which are described above, there are a number of other factors inherent in the modeling can affect the accuracy and precision of this analysis including the selection of the high exposure scenarios, the quality of the input data, the ability of the models to represent the real world, and the number of years that were modeled.

Scenarios that are selected for use in Tier 2 EEC calculations are ones that are likely to produce large concentrations in the aquatic environment. It should represent a site that really exists and would be likely to have the pesticide in question applied to it. It should be extreme enough to provide conservative estimates of the EEC, but not so extreme that the model cannot properly simulate the fate and transport processes at the site. Currently, sites are chosen by best professional judgement to represent sites which generally produce EEC's larger than 90% of all sites use for that crop. The EEC's in this analysis are accurate only to the extent that the site represents this hypothetical high exposure site.

The quality of the analysis is directly related to the quality of the input parameters. In general, the fate data for carbaryl are good. The paucity of soil and aquatic metabolism data is the main limitation of the data set. Because metabolism values are set to the upper 90% confidence limit of the mean, the EEC's will be conservative to the extent we are uncertain of the true central tendency of the metabolism data. Additional metabolism data would greatly increase our confidence, and likely reduce our EEC estimates. As noted above, using best estimates for "average" application practice rather than the standard upper bound estimates reduced the EEC from 125 $\mu g\ L^{-1}$ to 78.9 $\mu g\ L^{-1}$. This indicates that the quantity and quality of the metabolism data can substantially effect the estimates.

The models themselves represent a limitation on the analysis quality. While the models are some of the best environmental fate estimation tools available, they have significant limitations in their ability to represent some processes. Spray drift is estimated as a straight 16% of the application rate reaching the reservoir for each application. In actuality, this value should vary with each application from zero when the wind blows away from the reservoir to perhaps as high as 20%. A second major limitation of the models is the lack of validation at the field level for pesticide runoff. While several of the algorithms (volume of runoff water, eroded sediment mass) are well validated and well understood, there is less confidence that PRZM 3.12 well represents the amount of pesticide transported in runoff events. Some validation efforts undertaken by the pesticide industry and under review by the Agency indicate that PRZM gives reasonable estimates of pesticide extraction into runoff, but validation of the runoff portion of PRZM is not extensive. Another limitation of the models used is their inability to handle within-site variation (spatial variability), lack of crop growth algorithms, and an overly simple soil water transport algorithm (the "tipping bucket" method). A final limitation is that only thirty years of weather data were available for modeling at each site. Consequently there is approximately a 1-in-20 chance that the true 10% exceedance EEC's are larger than the maximum EEC in the calculated in the analysis. If the number of years of weather data could be increased it would increase the confidence that the estimated value for the 1-in-10 year exceedance EEC was close to the true value.

Drinking Water and Aquatic Exposure Issues Related to Urban Usage

BEAD has indicated that as much as 50 percent of carbaryl usage is in residential and 'urban' uses. The OPP currently does not have the capability to model the hydrology for urban watersheds and consequently cannot generate upper-bound estimates of carbaryl or other urban-use pesticides, as it can for agricultural pesticide uses. As noted in the main EFED RED chapter, monitoring data for carbaryl in urban watersheds does exist and carbaryl has been found in urban watershed in concentrations up to 3.2 $\mu g\ L^{-1}$ and is found much more frequently than in agricultural watersheds, with detection in roughly 45% of the samples. However, these concentrations detected in urban drainages are not high enough to exceed level of concern thresholds for either human health through drinking water or for fish. Exceedances of risk thresholds for aquatic invertebrates might be expected based on this data, but these data indicate that would occur infrequently.

It is worth noting, however, that because monitoring data samples are collected only infrequently in time, the peak concentrations for carbaryl at any location are unlikely to be detected and therefore acute exposure will generally be underestimated using monitoring data. Because carbaryl degrades rapidly, it is particularly difficult to capture the high concentrations that occur by monitoring. We are aware that the Office of Water is currently developing a urban scenario for the Castro Valley in California in order to assess exposure to copper derived from brake pad dust. The model being used, HSPF, must be highly calibrated and may not be suitable as a pesticide assessment tool without substantial monitoring data in the basin for calibration purposes and without good information on the distribution of non-agricultural pesticide use within the watershed. In addition, OPP needs to be able to identify and model sites which would be expected to be high exposure sites relative to all urban basins and there is no assurance that the Castro Valley scenario would meet that criteria. We will continue to stay abreast of model developments in this area, but have concluded that the best estimate of exposure to carbaryl in urban area at the present time is provided by the monitoring described in the EFED risk assessment. Monitoring data exists that does not show any risk exceedances for carbaryl, but it is likely to underestimate the true exposure. Modeling tools and data needed to estimate upper-bound estimates of carbaryl resulting from urban uses are at a developmental stage.

For aquatic risk concerns, it is worth noting that risks due to pesticides are not likely to be the greatest threat to wildlife in urban basins. Urban watersheds are beset by many other environmental threats including scouring due rapidly increasing flows during storms, sediment load, and thermal problems due loss of canopy and heating of storm water on pavement. As noted above, occasional exceedances of some aquatic life risks are expected to occur for carbaryl, but the risks are in most cases going to be outweighed by these other stressors in urban watersheds.

Literature Citations

Environmental Fate and Effects Division. 2002b. Pesticide Root Zone Model (PRZM) Field and Orchard Crop Scenarios: Standard Procedures for Conducting Quality Control and Quality Assurance. http://www.epa.gov/oppefed1/models/water/qa_qc_documentation_ver2.htm/

Appendix
Input Files for Estimating Drinking Water Exposure for Total Carbaryl Residues.

Table C-1. Input files archived for azinphos methyl applied to pome fruits.

File Name	Date	Description
W03813.dvf	July 3, 2002	weather data for the Georgia peach scenario
W12842.dvf	July 3, 2002	weather data for Florida citrus scenario
W14637.dvf	July 3, 2002	weather data for Pennsylvania apple scenario
W23155.dvf	July 3, 2002	weather data for the California citrus scenario
W93805.dvf	July 3, 2002	weather data for the Georgia pecan scenario
Cacitrus.txt	October 12, 2002	California citrus scenario parameters for PE3 shell
Gapeaches.txt	October 12, 2002	Georgia peaches scenario for the PE3 shell
GApecans.txt	May 23, 2003	Georgia pecans scenario for the PE3 shell
Flcitrus.txt	October 12, 2002	Florida citrus scenario parameters for PE3 shell
PAapple.txt	October 12, 2002	Pennsylvania apple scenario parameters for PE3 shell
Input Data Files for specific simulations (.PZR extension)		
Cacits13	May 16, 2003	maximum national use pattern, aerial California
Cacits14	May 16, 2003	California maximum use pattern
Cacits15	June 3, 2003	California max use pattern, spray blast
Cacits16	June 3, 2003	California 1 app, 12 lb, spray blast
Cacits17	June 3, 2003	California 1 app, 8 lb, spray blast
Cacits 18	June 3, 2003	California national max use pattern, spray blast, part 1
Cacits19	June 3, 2003	California national max use pattern, spray blast, part 2
FLCits12	June 3, 2003	Florida national max use pattern, aerial, part 1
FLCits13	June 3, 2003	Florida national max use pattern, aerial, part 2
FLCits14	June 3, 2003	Florida national max use pattern, 14 day interval, sb, part 1
FLCits15	June 3, 2003	Florida national max use pattern, 14 day interval, sb, part 2
FLCits16	June 3, 2003	Florida, 2 apps 4 lb, 14 day interval, spray blast
FLCits17	June 12, 2003	Florida 7.5x2, 4x1, 14 day interval, spray blast
FLCits20	June 20, 2003	Florida 2 apps, 10 lb acre, 14 day interval, spray blast
GApech00	May 16, 2003	Georgia peaches, maximum use pattern
GApecn00	May 27, 2003	Georgia pecans, maximum use pattern
GApecn01	June 5, 2003	Georgia pecans, maximum pattern, but spray blast
GApcn02	June 5, 2003	Georgia pecans, 2.5 lb two times, 10 day interval SB
PAAppl06	June 3, 2003	apples, replacement maximum use
PAAppl07	June 3, 2003	apples, replacement maximum use pattern, SB
PAAppl08	June 3, 2003	apples, 3 lb, 3 applications, spray blast

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